MEMS Wafer-Level Test Challenges:

Applications, Solutions and Future Visions

Frank-Michael Werner
MEMUNITY

(SUSS MicroTec Test Systems)

Outline

1. Wafer-level MEMS test challenges
2. How to perform wafer-level test of…
   - Pressure Sensors
   - Acceleration & Yaw Rate Sensors
   - Micro-Bolometer
   - Si-Microphones
3. Future outlook …

Outline

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IC On-Wafer Test

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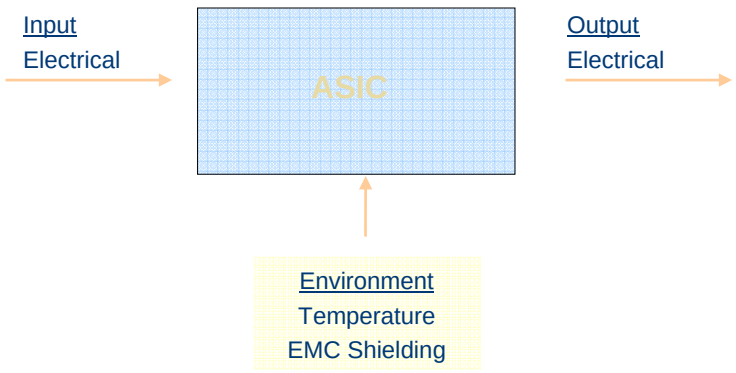
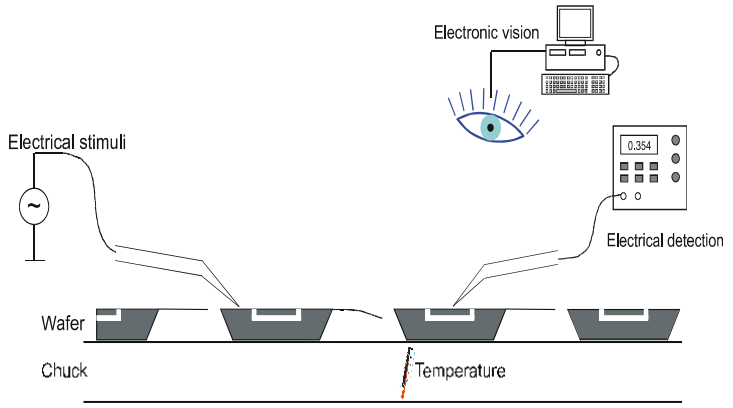
Input, Output and Environment



Examples of Input & Output



MEMS On-Wafer Test

Input, Output and Environment

Input
Physical Stimuli

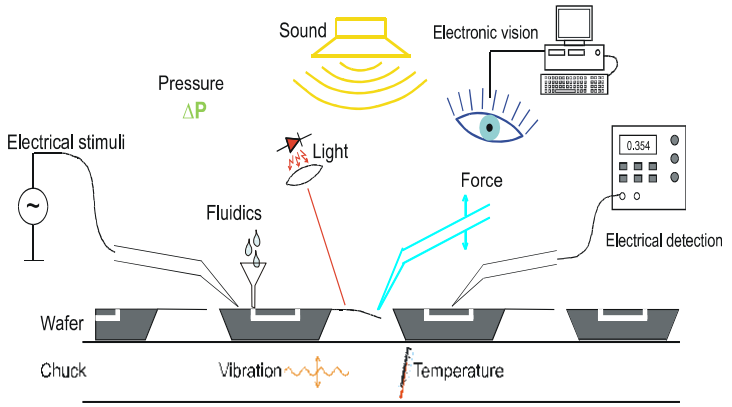
MEMS SENSOR

Output
Electrical / Optical

Environment

Temperature	EMC
Light	Gas
Humidity	Pressure
Vibration	

Examples of Input & Output



Generic Platform

Open Platform

- Acceleration, Jaw rate
- Cantilever, Mechanical Force
- Microphone
- Optical
- Biochemical sensors

Enclosed Platform

- Pressure
- Gases
- Humidity
- EMC, light and sound shielded

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Pressure Sensors

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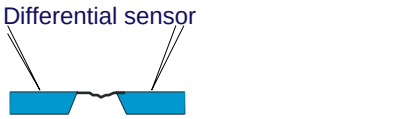
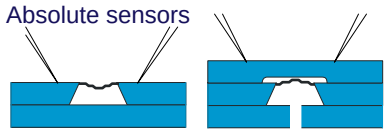
Typical data for pressure sensors
- Leakage current
- Off-set
- Sensitivity

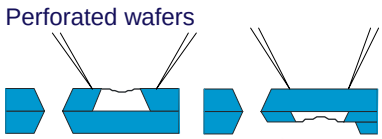
Valuable information
- Quality of manufacturing process
- Packaging process

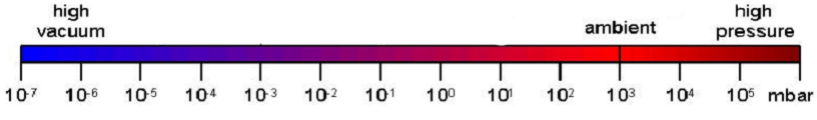
Reduces test on packaged sensors

Calibration reduces final electrical test on pressure sensors with regard to wafer level offset.









Principles for Testing Pressure Sensors

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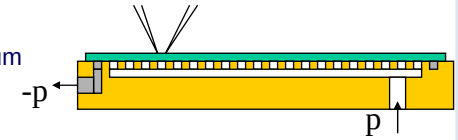
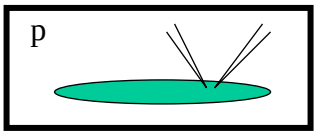
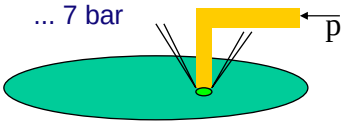
1. On pressure chuck
   - → positive pressure range, vacuum
   - → chuck pattern = wafer pattern
   - → low-priced ratio



2. Inside pressure chamber
   - → pressure range up to 50 bar
   - → few limitations
   - → expensive



3. Under impact pressure
   - → very flexible, upgrade
   - → absolute & differential sensors
   - → good price-performance



Pressure Chuck

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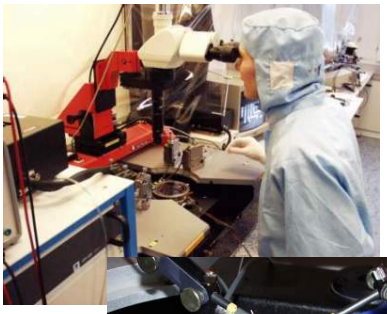
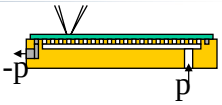
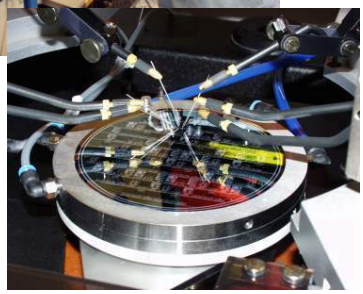
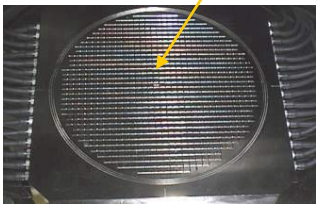




- Applies pressure from backside
- Pressure range:
  rough vacuum → low overpressure
- Can be used with all probers



Matrix pattern



Semiautomatic Pressure Prober

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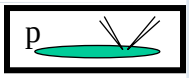

A Prober inside a high pressure chamber

- Pressure range: rough vacuum ➔ 50 bar
- Pressure regulation

Optional:

- Controlled temperature
- Non-aggressive gases
- Controlled humidity
- Acceleration chuck

PressureProbe Module PPM

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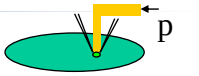

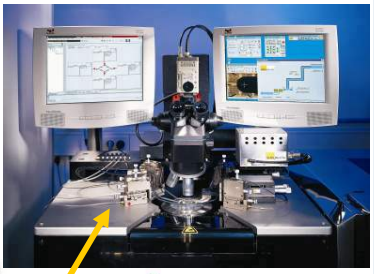

- Applies pressure from the topside
- Optional temperature control prevents cooling of sensor's diaphragm
- Can be used with manual, semi- and fully-automatic wafer probers

Accuracy of test set-up

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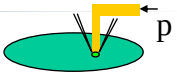
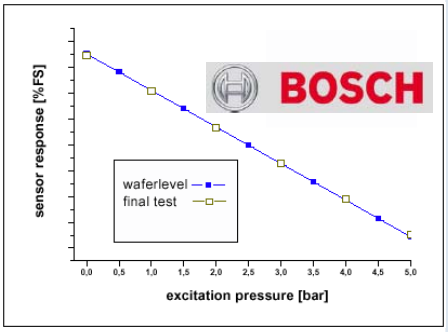


Correlation analysis with different sensor types:

- Wafer-level test with pressure excitation @ 25°C, different sensor types
- Dicing
- Assembly on reference material
- Final characterization @ 25°C

Specified accuracy of 1% shown @ 25°C



Source: Holger Ross, "Waferlevel- Test of Pressure Sensors using Süss Pressure Probe Module", MEMUNITY Workshop, March 2006

Results from Testing

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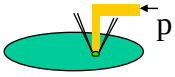

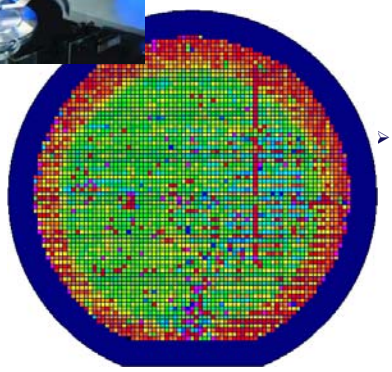

- Piezo-resistive differential pressure sensor (2,5bar)
- Applying pressure by nozzle from above (SUSS Pressure Probe Module)

DUT within spec

DUT out of spec

- Electrical test result identifies a few bad dies

The non-electrical test identifies the sensitivity problem in the edge areas.

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Acceleration & Yaw Rate Sensors
Vacuum Prober

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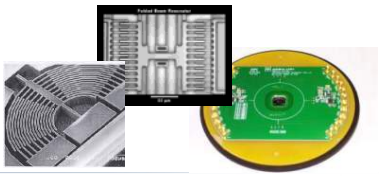
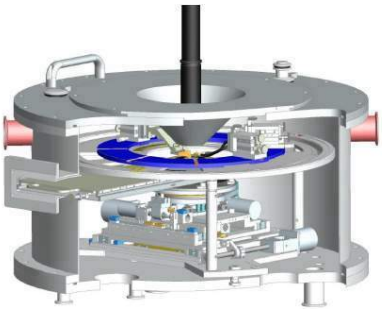
SUSS PMV150

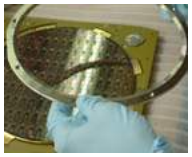
SUSS PAV200

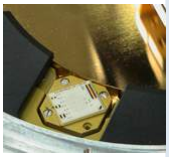
- Test before hermetic packaging
- Manual and semiautomatic stations
- Probing in controlled inert gas or vacuum environment
- Pressure range: HV – ambient
- Pressure regulation
- Wafer size 150 mm / 200 mm
- Probe card with symmetric read-out electronics on-top
- DC or HF probes
- Thermal chuck –65°C ... 200°C
- Polytec's MSA / MSV



Acceleration & Yaw Rate Sensors
Vacuum Prober







Acceleration & Yaw Rate Sensors
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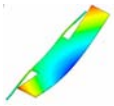
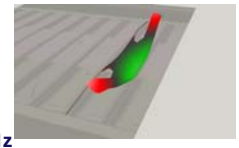
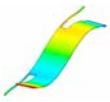
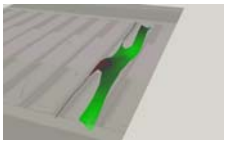


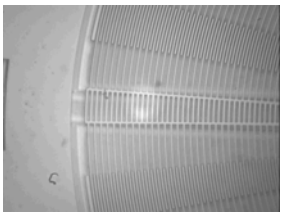
62,81 kHz



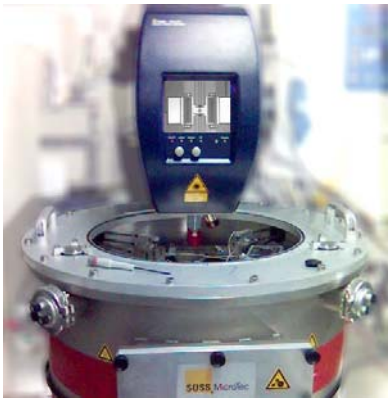


149,1 kHz





Combination of electrical and non-electrical measurements



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Micro-Bolometer

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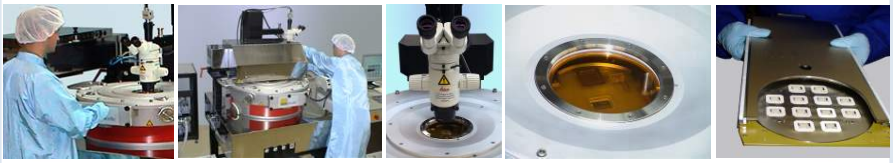
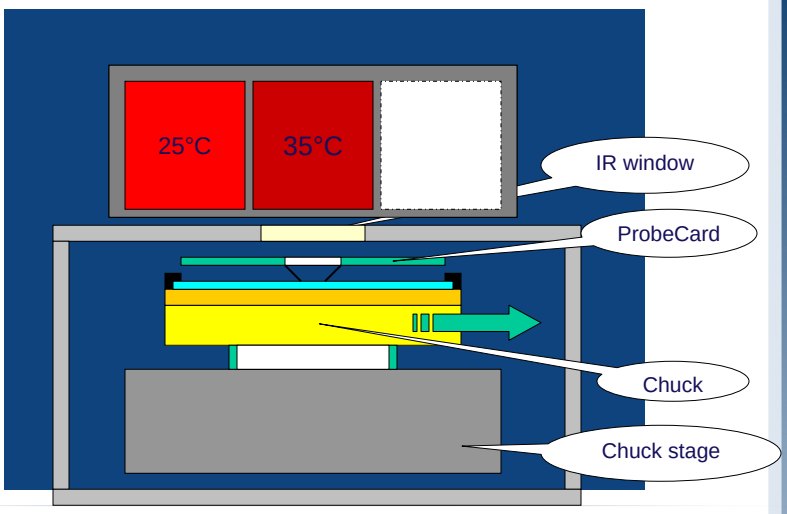
- Testing in a vacuum environment to prevent heat transfer by convection
- Expose DUT with controlled wavelength 2 … 18µm
- Video electronics close to probe tips
- Semiautomatic operation
- Typical high vacuum range: 10^{-3} … 10^{-4} mbar
- 150mm 200mm wafer or substrates
- Single substrate carrier
- Automatic chip alignment
- IR radiation transmission window
- IR black-bodies, filter shutter, iris aperture



Micro-Bolometer Test



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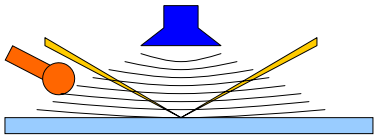
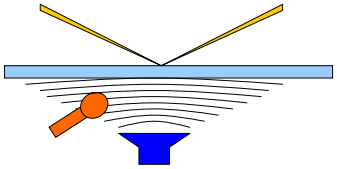
Si-Microphones

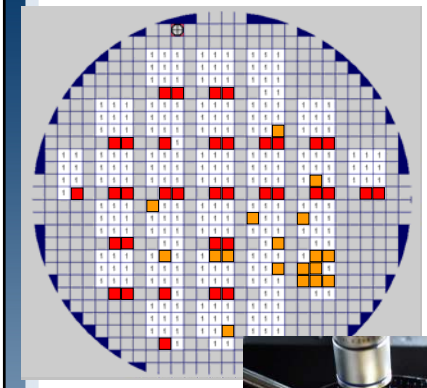


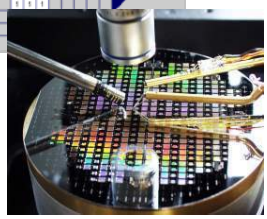


- Microphone's membrane and bond pads on wafer's top-side
- Sound source placed near DUT
- Reference microphone placed near DUT
- Application of reproducible, defined sound pressure

- Membrane on wafer's backside and bond pads on wafer's topside
- Needs double-side prober concept and follow-me mode
- Sound source and reference microphone close together

Actual Results from Si-Microphone Testing





Top-side electrical and acoustical test with reference microphone

- Passed all tests – 251 dies
- Failed electrical test – 18 dies (6.7%)
- Passed electrical but failed acoustic test – 36 dies (13,4%)

If only an electrical test was carried out, more than double of the bad devices would have been packaged!

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Future outlook

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Are the available MEMS wafer-level test solutions...

Complete ?	➢ **Test solutions for most established MEMS devices**
	➢ **Testing in ambient or extreme environments**
Flexible ?	➢ **Achieve several setups with one system**
	➢ **Provides both electrical and non-electrical stimulation and measurement**
Modular ?	➢ **Solutions for each step in the life of a MEMS device – from manual R&D systems to fully-automated production floor systems**
	➢ **Different measurement tools and instruments can be seamlessly integrated in one system**

Future outlook

What comes next?

- New devices
  - Micro-fluidics
  - Bio-MEMS
  - ...
- New test strategies?
- New test approaches?
- …

Test strategy

↘

Test technique, ~ technology

↘

Test equipment, ~ tools

We would like to discuss this with you here.

Conclusion

- Wafer-Level MEMS test is a modern method to save manufacturing costs and time to market
- Modern MEMS tests use non electrical stimuli
- MEMS test setups are mostly unique but platforms are available
- MEMUNITY is an open community with other experts in MEMS test to help you find the solution you need
- → MEMUNITY supports you in developing your test strategy.

Thank you!

Further information:

http://www.memunity.org

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